ASSESSMENT OF EFFECTS OF RODENT REMOVAL ON ARTHROPODS, AND DEVELOPMENT OF ARTHROPOD MONITORING PROTOCOLS, ON CONSERVATION LANDS UNDER US ARMY MANAGEMENT

Annual Statement of Work, November 2014

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Background

Invasive black rats are believed to exert severe predatory pressure on native arthropod species, but the effects of this pressure on arthropod populations has not been quantified in the field. Because rats are now nearly ubiquitous in natural areas of Hawaii, the most effective way to assess their impacts on arthropod species and communities is to monitor the response of arthropods to rat removal. The Oahu Army Natural Resource Program (OANRP) has implemented rat removal operations in several areas in the Waianae Mountains. In conjunction with these efforts, I have been conducting standardized, quantitative arthropod sampling before and after rat removal in two of these areas (Kahanahaiki and Palikea), as well as in adjacent control sites where rats will not be immediately removed, to measure arthropod responses and estimate the impacts of rats on native and introduced arthropod populations. This sampling will also serve as an arthropod inventory, providing important information on the biodiversity of these management areas. Thirdly, the sampling conducted in this project will be used to help develop broader arthropod monitoring protocols for the OANRP management units, as desired under the Makua and Oahu Implementation Plans.

FY14 progress

During fiscal year 2014, work on this project included the second year of once-annual (as opposed to seasonal) monitoring at Palikea, during July 2014. This represents the fourth year of post-rodent trapping monitoring, and will provide a good picture of medium-term response of arthropod communities to this management action. Sampling at Kahanahaiki was terminated in late FY12, as new rat trapping technology was implemented at the adjacent control site (Pahole Natural Area Reserve) for the Kahanahaiki monitoring. The record of arthropod response therefore includes monitoring data up to three years post-rodent trapping at this site.

A total of 144 standardized samples were collected in the course of the July 2014 monitoring event, including pitfall traps, leaf litter extraction, daytime vegetation sweeping and nighttime vegetation sweeping. This sampling was conducted within OANRP's vegetation monitoring plots, allowing analysis of relationships between plant community composition and arthropod community composition. In addition, *Rhynchogonus* beetle monitoring was conducted at 50 points during the monitoring event.

Sample sorting and specimen identification progressed during FY14. All samples up through the July 2013 monitoring event have been sorted at least to taxonomic order, and specimen identification to lower taxonomic levels has proceeded for much of this material. Sorting of samples from the July 2014 monitoring event has begun.

All specimens from all monitoring events at Kahanahaiki/Pahole, and from all monitoring events from the first three years at Palikea (three seasonal events each for the year prior to rodent trapping initiation and the first two years after trapping), have now received final treatment. Final determinations have been made and biomass measurements have been completed. A total of over 270,000 specimens belonging to over 570 taxa have now been databased in the project. This has allowed for final dataset compilation and analysis to begin for these monitoring events.

<u>Partial results</u>

Preliminary results for Kahanahaiki have been reported in previous summaries, so I will focus on the most recent results for the Palikea site in this summary.

Changes in arthropod abundances

Relative changes in abundance for the major orders collected, and some subgroups within these orders, at one year and two years post trapping are tabulated for arboreal and terrestrial arthropod communities in Table 1. The numbers presented are the median increase or decrease in abundance, per plot, over time at the rat removal site relative to the control site (no rat trapping) over the same time period. Positive values correspond to increases in abundance at the removal site relative to the control site, and negative values indicate the opposite trend. Also presented are the associated p values for the Wilcoxon Signed Rank Test assessing the probability of these medians differing from zero (i.e. no relative change in abundance). Medians significantly different from zero at an α of 0.05 are highlighted in bold and color coded green for relative increases and red for relative decreases at the removal site. These analyses were performed on the annual totals for each plot, pooling the data from the three seasonal sampling events during each year. Because of the large number of statistical tests conducted in each table, some spurious significant results arising from sampling error can be expected, and focus should be directed at recurring patterns rather than individual outcomes.

For arboreal arthropod communities (assessed with day and night vegetation sweeping), native Hemiptera increased significantly at the removal site at one year post-trapping, and showed a similar magnitude of increase in the second year but greater variation among plots produced a statistically insignificant result for the second year. Hymenoptera increased in abundance in both years, and this increase resulted in substantial part from positive changes in the abundance of native *Sierola* wasps (although the change in *Sierola* alone was not quite significant). Most of the remainder of the increase can be attributed to unidentified parasitic Hymenoptera (not shown). *Eupithecia* caterpillars (mainly the predatory species *E. orichloris*) increased significantly in year two, consistent with patterns obtained in terrestrial samples at Palikea (below) and results from Kahanahaiki (not shown). Lepidoptera more generally did not show patterns of increase in the arboreal samples, in contrast to preliminary results from Kahanahaiki. Like Kahanahaiki, Psocoptera showed consistent patterns of decreasing abundance at the removal site relative to the control site.

One of the strongest patterns has been an increase in abundance in Orthoptera at the removal site after trapping began. For the first two years, this increase has been statistically significant only for native *Laupala* crickets (family Gryllidae), although native *Banza* katydids (family Tettigoniidae) showed non-significant trends towards recovery as well. This pattern has persisted and strengthened in the third year post-trapping, in which the increase in *Banza* was also statistically significant (see Figure 1; note that trends for years 1 and 2 were assessed for the entire annual datasets, whereas the trend for year 3 compares only July of 2010 with July of 2013 due to the termination of seasonal sampling in 2013). The post-trapping increases shown in Figure 1 correspond to an approximate doubling in abundance of *Laupala* crickets and a three- to four-fold increase in abundance of *Banza* katydids.

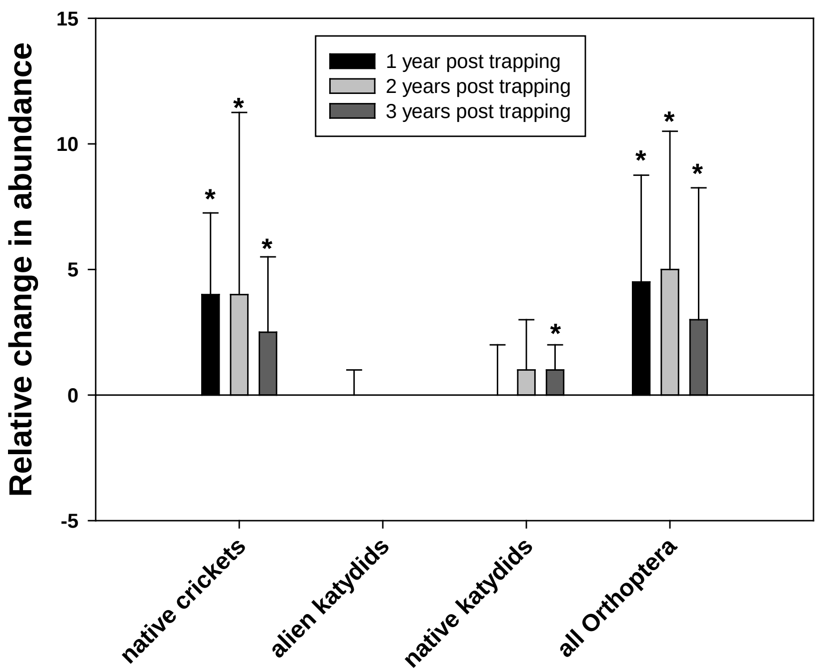

Figure 1. Changes in median abundances, per plot, of Orthoptera at the rodent removal site relative to the control site, at one, two and three years after trapping began. Note that year 3 median changes are not directly comparable to years 1 and 2 in magnitude, because data represent only one sampling event in year 3 but pool 3 seasonal events for years 1 and 2. Relative changes significantly different from zero marked with asterisk ($p < 0.05$), bars indicate 75th percentile of values.

For terrestrial arthropod communities (assessed with pitfall traps and leaf litter extraction), millipedes (Diplopoda) and, as mentioned above, *Eupithecia* caterpillars consistently increased after rat trapping. *Hyposmocoma* case-making caterpillars also showed signs of increasing after trapping, mainly after two years, but caterpillars as a whole and Lepidoptera overall significantly decreased in ground samples at two years post-trapping. Spiders, particularly adventive species, and to a lesser extent adventive amphipods, showed a recurring pattern of decreasing at the removal site after trapping began.

Changes in total arthropod abundances were generally non-significant, with the exception of an increase in native terrestrial arthropods (taken as a group) two years after trapping. Because there was also a nearly significant increase in arboreal native arthropods after two years, it will be interesting to see if this pattern strengthens in years three and four.

The results to date suggest that a few taxonomic groups tend to respond to rodent trapping at each site, while many do not. Comparison with preliminary results from Kahanahaiki also suggests that the same groups do not always respond in the same way at different sites. Some responses may result from direct release from rodent predation, while other responses may arise through indirect pathways, wherein the direct effects caused by changes in rodent densities cascade to other groups through changes in intermediate predator or competitor densities (potentially including both arthropod and vertebrate intermediate predators). Measured responses among Psocoptera, Hymenoptera, Collembola and small Hemiptera seem especially likely to have resulted through the latter mechanism. Between-site differences in the larger biological community may contribute to differences assessed among arthropods.

Changes in species richness

Relative changes in richness, per plot, are presented in Table 2 for groups that are diverse and that were identified to the level of species/morphospecies across all samples. These are the orders Araneae (spiders), Coleoptera (beetles) and Hemiptera (true bugs), plus the native moth genus *Hyposmocoma*, for arboreal communities, and Araneae, Coleoptera and *Hyposmocoma* for terrestrial communities. Remaining orders either had relatively few species, or were sorted only to higher taxonomic levels for most samples (the latter category includes Diptera, Psocoptera, Hymenoptera, and Lepidoptera). Median changes in relative richness and their p values were calculated in the same manner as for abundances, described above.

Spiders exhibited a relatively consistent pattern of decreasing richness in both arboreal and terrestrial communities. This pattern was strongest among native arboreal species, but declines in total spider richness were also significant one year after trapping in arboreal samples and two years after trapping in ground samples. Conversely, Hemiptera had a fairly consistent pattern of increasing richness after trapping began. Coleoptera only showed evidence of increasing richness at two years post-trapping among terrestrial communities, with the change in overall richness being significant, and changes in both native and adventive subsets of species being relatively close to statistically significant.

Evidence for increases in total community species richness after trapping was strongest for native terrestrial arthropods, with some indication of increasing adventive species richness in arboreal communities after two years. Overall, changes in richness were relatively small in magnitude, and tended to mirror the changes in abundances that were measured.

Changes in trophic structure

Relative changes in biomass, categorized by trophic group, and relative changes in percent composition of arthropod communities by trophic group, are given in Table 3. Median biomass is presented in mg of dry weight, while median changes in percent composition are given in the lower portion of the table. Presentation and analyses are as described above for abundances and species richness.

There were no significant changes in biomass over time for any of the trophic groups in either arboreal or terrestrial communities. The percent composition by trophic group, however, did change significantly at two years post-trapping. In arboreal communities, the herbivore fraction increased significantly at the removal site relative to the control site, mainly at the expense of the carnivore fraction. In terrestrial communities, the herbivore fraction declined significantly, mainly in concert with a relative increase in detritivores. These trophic shifts were fairly small in magnitude, however, and are illustrated graphically in Figures 2 and 3.

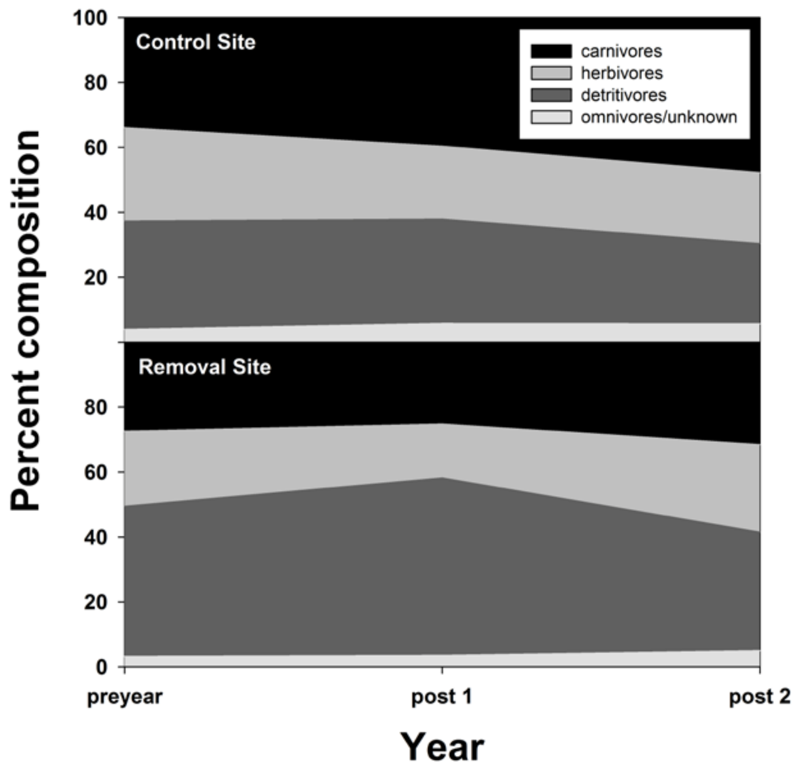

Figure 2. Changes in trophic structure over time in arboreal arthropod communities at the Palikea rodent removal and control sites. Percent composition of trophic groups is measured in biomass and averaged over all plots at each site.

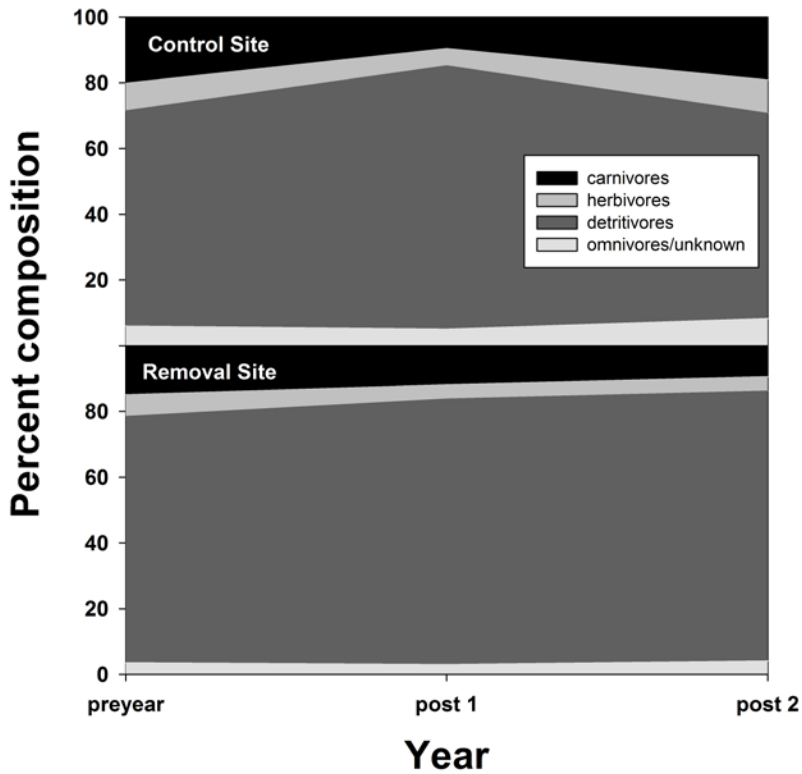

Figure 3. Changes in trophic structure over time in terrestrial arthropod communities at the Palikea rodent removal and control sites. Percent composition of trophic groups is measured in biomass and averaged over all plots at each site.

While trophic shifts over time were moderate, the graphs do indicate large differences in trophic composition between arboreal and terrestrial communities, with terrestrial communities dominated by detritivores, and arboreal communities more evenly split between carnivores, herbivores and detritivores.

FY15 plans

Funding for FY15 will allow continued identification of the July 2013 monitoring material, and the sorting and identification of the July 2014 monitoring event samples. This will allow an assessment of the response of arthropod communities up to four years after rodent trapping was implemented. Analysis, synthesis and write-up of final datasets for the first three years of post-trapping data for both sites is planned for FY15. (Reference to this project, and some preliminary results, were made in the 2013 publication: Medeiros, M.J., J.A. Eiben, W.P. Haines, R.L. Kaholoaa, C.B.A. King, P.D. Krushelnycky, K.N. Magnacca, D. Rubinoff, F. Starr and K. Starr. 2013. The importance of insect monitoring to conservation actions in Hawaii. Proceedings of the Hawaiian Entomological Society 45: 149-166).

FY15 plans also include initiation and significant progress on the new *Solenopsis* component of the project. Plans include conducting bait preference tests to determine optimal baits for both non-destructive monitoring and for suppression/control; determination of field plot locations for pre- and post-control monitoring of arthropod communities; and initiation of *Drosophila* rearing and monitoring methods specific to the goals of the project.

Table 1. Relative changes in median abundance, per plot, of arthropods at the Palikea rodent removal site relative to the control site, at one and two years after rodent trapping was initiated. See text for details.

	Palikea							
	Vegetation sampling				**Ground sampling**			
	1 year		**2 years**		**1 year**		**2 years**	
Group	**median**	**p**	**median**	**p**	**median**	**p**	**median**	**p**
Chilopoda total	1.00	0.088	-1.00	0.245	-1.00	0.586	-2.00	0.381
Diplopoda total	5.00	0.394	-3.00	0.535	**18.00**	**0.002**	**17.00**	**0.001**
Amphipoda total	1.50	0.064	**-0.50**	**0.050**	-22.50	0.384	**-54.50**	**0.007**
native Amphipoda	0.00	0.593	-0.50	0.063				
adventive Amphipoda	1.50	0.075	0.00	0.638	-22.50	0.384	**-54.50**	**0.007**
Isopoda (all adventive)	-5.00	0.571	-1.50	0.760	-53.50	0.486	-63.50	0.360
Acari	-50.00	0.058	2.00	1.000	-5.50	1.000	133.00	0.486
Araneae total	-16.50	0.384	16.50	0.223	**-19.00**	**0.003**	-9.00	0.065
native Araneae	-19.00	0.184	7.00	0.472	0.00	0.979	-1.00	0.381
adventive Araneae	-1.00	0.679	-0.50	0.811	**-12.00**	**0.005**	**-6.00**	**0.044**
Archaeognatha (all native)	-0.50	0.107	0.00	0.260				
Blattaria (all adventive)	-2.00	0.368	-1.50	0.570	0.00	1.000	0.00	0.181
Coleoptera total	-0.50	0.868	1.50	0.695	0.50	0.965	8.00	0.108
native Coleoptera	0.50	0.879	-0.50	0.868	-0.50	0.959	3.00	0.139
adventive Coleoptera	0.50	0.647	2.50	0.163	1.00	1.000	**2.50**	**0.041**
Collembola total	58.00	0.433	**62.50**	**0.045**	-108.50	0.139	-101.00	0.191
Dermaptera total					-1.00	0.528	1.00	0.758
native Dermaptera					0.00	0.374	-0.50	0.507
adventive Dermaptera					-0.50	0.287	0.50	0.460
Diptera total	-1.00	0.856	3.50	0.601	10.00	0.082	-1.50	0.728
Hemiptera total	14.50	0.074	17.00	0.258	-1.00	0.695	0.50	0.717
native Hemiptera	**12.50**	**0.043**	10.00	0.177	0.50	0.776	0.50	0.410
adventive Hemiptera	1.50	0.616	2.50	0.663	0.50	0.623	0.00	0.959
Hymenoptera total	**11.00**	**0.045**	**22.00**	**0.009**	0.50	0.433	-1.00	0.215
native Hymenoptera (mainly Sierola)	5.00	0.053	4.00	0.148	0.00	0.100	0.00	0.465
adv Hymenoptera (mainly Formicidae)	1.50	0.132	1.50	0.221	0.00	0.730	**-1.50**	**0.028**
Lepidoptera total	1.00	0.948	0.50	0.887	-7.50	0.601	**-26.50**	**0.041**
immature Lepidoptera total	0.00	0.897	1.50	0.096	-13.00	0.459	**-32.50**	**0.006**
immature Hyposmocoma	-4.00	0.327	-2.00	0.670	4.00	0.267	**8.50**	**0.039**
immature Eupithecia	0.00	0.878	**1.00**	**0.026**	**0.50**	**0.050**	**0.50**	**0.022**
Neuroptera total	0.00	0.294	-0.50	0.221				
native Neuroptera	0.00	0.181	0.00	0.059				
adventive Neuroptera	0.00	0.893	0.00	0.787				

Orthoptera total	**4.50**	**0.007**	**5.00**	**0.008**	0.00	0.859	0.00	0.889
native Orthoptera	**4.00**	**0.015**	**6.00**	**0.005**	0.00	0.859	0.00	0.889
adventive Orthoptera	0.00	0.236	0.00	0.116				
Gryllidae (all native Laupala)	**4.00**	**0.022**	**5.00**	**0.008**	0.00	0.859	0.00	0.889
Tettigoniidae total	1.00	0.233	0.00	1.000				
native Tettigoniidae (Banza)	0.50	0.363	1.00	0.196				
adventive Tettigoniidae	0.00	0.236	0.00	0.116				
Psocoptera total	**-24.50**	**0.010**	**-18.00**	**0.017**	9.00	0.118	-7.50	0.177
Thysanoptera total	4.50	0.102	5.50	0.098	-9.00	0.571	-14.00	0.327
Arthropoda total	36.50	0.896	93.50	0.207	-182.00	0.663	-194.50	0.327
native Arthropoda	5.00	0.862	32.00	0.068	1.50	0.636	**10.00**	**0.037**
adventive Arthropoda	6.00	0.647	4.00	0.795	-86.00	0.372	-120.00	0.267
unknown status Arthropoda	45.00	0.777	72.50	0.163	-83.00	0.828	-19.50	0.965

Table 2. Relative changes in median species richness, per plot, of arthropods at the Palikea rodent removal site relative to the control site, at one and two years after rodent trapping was initiated. See text for details.

	Palikea							
	Vegetation sampling				Ground sampling			
	1 year		2 years		1 year		2 years	
Group	**median**	**p**	**median**	**p**	**median**	**p**	**median**	**p**
Araneae total	**-2.50**	**0.007**	-1.50	0.106	-0.50	0.587	**-1.50**	**0.016**
native Araneae	**-2.00**	**0.018**	**-1.50**	**0.004**	0.00	0.754	-0.50	0.266
adventive Araneae	-0.50	0.569	0.50	0.286	0.00	0.737	-1.00	0.109
Coleoptera total	-0.50	0.518	1.00	0.379	1.00	0.156	**3.00**	**0.041**
native Coleoptera	0.50	0.501	0.50	0.623	1.00	0.103	1.00	0.088
adventive Coleoptera	-0.50	0.508	0.50	0.777	0.00	1.000	1.00	0.058
Hemiptera total	**3.00**	**0.010**	3.00	0.052				
native Hemiptera	**2.50**	**0.010**	2.00	0.313				
adventive Hemiptera	1.00	0.267	**2.00**	**0.050**				
immature Hyposmocoma	-1.00	0.066	-1.00	0.142	0.50	0.308	1.00	0.074
Arthropoda total	-1.00	0.879	3.00	0.218	2.00	0.223	4.50	0.071
native Arthropoda	0.00	0.962	-1.00	0.372	**2.00**	**0.030**	**3.00**	**0.031**
adventive Arthropoda	0.50	0.828	**3.00**	**0.028**	-0.50	0.551	1.00	0.245
unknown status Arthropoda	-1.00	0.449	0.00	0.977	1.00	0.281	0.50	0.538

Table 3. Relative changes in median biomass and trophic composition, per plot, of arthropods at the Palikea rodent removal site relative to the control site, at one and two years after rodent trapping was initiated. Biomass is in units of mg dry weight; lower portion of table indicates changes in percent composition of trophic groups (according to biomass contributions). See text for additional details.

	Palikea							
	Vegetation sampling				**Ground sampling**			
	1 year		**2 years**		**1 year**		**2 years**	
Group	**median**	**p**	**median**	**p**	**median**	**p**	**median**	**p**
carnivore biomass	13.60	0.571	-26.75	0.207	11.72	0.695	-20.43	0.514
herbivore biomass	4.50	0.571	7.58	0.695	-3.76	0.728	-16.09	0.127
detritivore biomass	54.86	0.191	-21.04	0.191	-12.28	0.965	31.60	0.728
omnivores and unknown biomass	-1.17	0.296	0.90	0.571	1.04	0.965	3.48	0.760
total biomass	63.97	0.127	-22.90	0.571	53.13	0.486	4.31	0.965
percent carnivore	-8.13	0.191	-13.96	0.055	3.40	0.601	-5.42	0.296
percent herbivore	2.59	0.433	**11.67**	**0.019**	1.13	0.514	**-3.42**	**0.050**
percent detritivore	5.69	0.384	0.20	0.931	-6.12	0.177	9.36	0.098
percent omnivore and unknown	-1.26	0.089	0.64	0.601	0.75	0.384	-0.68	0.663